Silent and Efficient Supersonic Bi-Directional Flying Wing

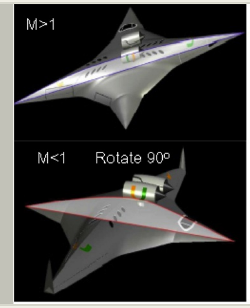
Completed Technology Project (2012 - 2014)

Project Introduction

We propose a Phase I study for a novel concept of a supersonic bi-directional (SBiDir) flying wing (FW) that has the potential to revolutionize supersonic flight with virtually zero sonic boom and ultra-high aerodynamic efficiency. The SBiDir-FW planform is symmetric about both the longitudinal and span axes. For supersonic flight, the planform can have as low aspect ratio and as high sweep angle as desired to minimize wave drag and sonic boom. For subsonic mode, the airplane will rotate 90deg in flight to achieve superior stable aerodynamic performance. The conflict of subsonic and supersonic aerodynamic performance of conventional fuselage-wing configuration is hence removed. The preliminary CFD simulation for a SBiDir-FW business jet (BJ) at Mach numbers of 1.6 and 2.0 indicates that the configuration generates no N-wave sonic boom on the ground at a high lift to pressure drag ratio L/Dp of 16. The superior supersonic aerodynamic performance is benefited from the sharp nose and ultra-slender body with a low aspect ratio of 0.33, which translates to a very high subsonic aspect ratio of 33 for high subsonic performance. This proposal has three objectives: 1) design refinement of a supersonic SBiDir-FW BJ configuration using CFD; 2) mission analysis assisted with CFD simulation for the supersonic SBiDir-FW BJ to study the feasibility; and 3) wind tunnel testing of the SbiDir-FW BJ to verify its supersonic aerodynamic performance and sonic boom signature. The research team is highly qualified to perform the proposed tasks.

Anticipated Benefits

We propose a Phase I study for a novel concept of a supersonic bi-directional (SBiDir) flying wing (FW) that has the potential to revolutionize supersonic flight with virtually zero sonic boom and ultra-high aerodynamic efficiency.



Project Image Silent and Efficient Supersonic Bi-Directional Flying Wing

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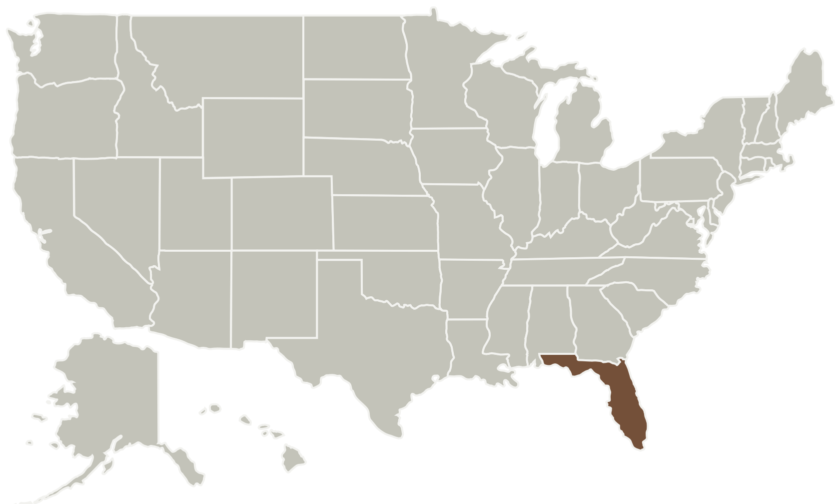
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Miami	Lead Organization	Academia	Coral Gables, Florida
Florida State University(FSU)	Supporting Organization	Academia	Tallahassee, Florida

Primary U.S. Work Locations
Florida

Project Transitions

September 2012: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Miami

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

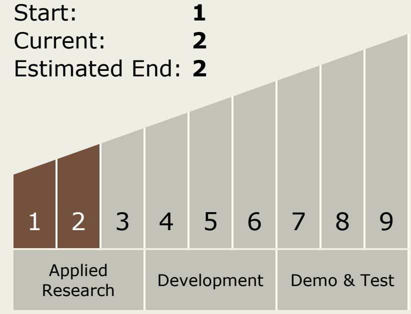
Eric A Eberly

Principal Investigator:

Gechang Zha

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **2**



October 2014: Closed out

Closeout Summary: The supersonic bi-directional (SBiDir) flying wing (FW) co ncept has a great potential to achieve low sonic boom with high supersonic aero dynamic performance due to removal of performance conflict between high spee d and low speed by rotating goo in flight. This NIAC Phase 1 research has achiev ed three objectives: 2) prove the concept based on simulation that it can achiev e very low boom with smooth Sine wave ground over-pressure signature and ex cellent aerodynamic efficiency; 3) conduct trade study to correlate the geometri c parameters with sonic boom and aerodynamic performance for further automa ted design optimization in Phase II. The design methodology developed in Phase I includes three parts: 1) an advanced geometry model, which can vary airfoil m eanline angle distribution to control the expansion and shock waves on the airpl ane surface to mitigate sonic boom and improve aerodynamic efficiency. 2) a val idated CFD procedure to resolve near field flow with accurate shock strength. Th e sonic boom propagation from near field to far field ground is simulated by NAS A NF Boom code. The surface friction drag prediction is based on fiat plate correl ation adopted by Seebass [1] and supported by the experimental study of Winte r and Smith [2], which is on the conservative side and is more reliable than CFD RANS simulation. 3) a mission analysis tool based on Corke's model[3] that prov ides design requirements and constraints of supersonic airplanes for range, payl oad, volume, size, weight, etc. The design mission target is a supersonic transpo rt with cruise Mach number 1.6, 100 passengers, and 4000nm range. The trade study has several very important findings: 1) The far field ground sonic boom si gnature is directly related to the smoothness of the flow on the airplane surface. The meanline angle distribution is a very effective control methodology to mitiga te surface shock and expansion wave strength, and mitigating compression wav e coalescing by achieving smooth loading distribution chord-wise. Compared wit h a linear meanline angle distribution, a design using nonlinear and non-monoto nic meanline angle distribution is able to reduce the sonic boom ground loudnes s by over 20dBP1. The design achieves sonic boom ground loudness less than 7 0dBP1 and aerodynamic dynamic efficiency 1/D of 8.4. 2) Decreasing sweep ang le within the Mach cone will increase 1/D as well as sonic boom. A design with v ariable sweep from 84° at the very leading edge to 68° at the tip achieves an ex traordinarily high 1/D of 10.4 at Mach number 1.6 due to the low wave drag. If no sonic boom constraint is attached, SBiDir-FW concept still has a lot of room t o increase the 1/D. 3) The round leading edge and trailing edge under high swe ep angle are beneficial to improve aerodynamic performance, sonic boom, and t o increase volume of the airplane. 4) Subsonic performance is benefited greatly from the high slenderness of supersonic configuration after rotating goo. A desig n with excellent supersonic aspect ratio of 0.44, 1/D of 8.g, gives an extraordina ry subsonic aspect ration of 10 and 1/D of 1g.7. Two configurations are designe d in details to install internal seats, landing gears, and engine installation to de monstrate the feasibility of SBiDir-FW configuration to acco=odate all the requir ed volume for realistic airplane. In summary, it is proved numerically that SBiDir -FW can achieve very low sonic boom and excellent aerodynamic performance fo r both supersonic and subsonic. It is discovered that the airfoil meanline angle di stributions are critical to mitigate far field sonic boom by achieving smooth surfa ce loading distribution with weak shock, expansion waves and compression wav e coalescing, whereas the sweep angle determining the aspect ratio has strong effect on aerodynamic efficiency of 1/D. It is expected that more improved desig ns will be achieved in Phase II with automated systematic design optimization. Here we emphasize that the qualitative findings in Phase I are very encouraging, more important than the quantitative results. Qualitative findings give the under

Technology Areas

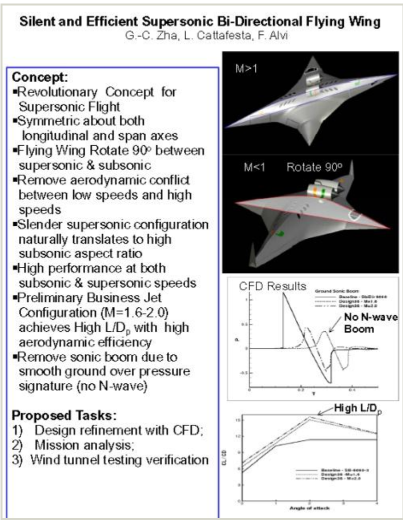
Primary:

- TX15 Flight Vehicle Systems
  - └ TX15.1 Aerosciences
    - └ TX15.1.1 Aerodynamics

Target Destination

Earth

Images



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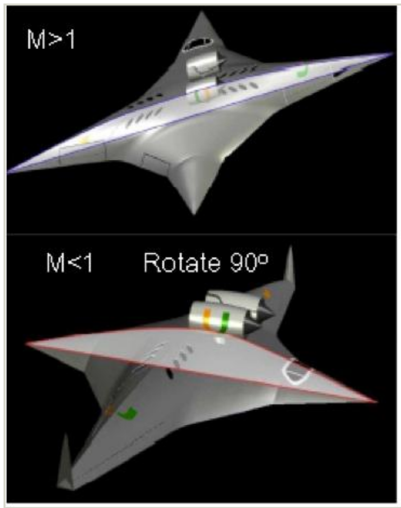
(https://techport.nasa.gov/image/102261)



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